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Pushing the Limits of TOF-PET Detectors: Advancements in Timing and DOI Evaluation

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Achieving excellent time resolution is crucial in time-of-flight (TOF) positron emission tomography (PET) for improving the signal-to-noise ratio and image quality. High-frequency (HF) front-end electronics offer a solution for achieving excellent performance in TOF-PET applications by exploiting the fastest light production mechanisms in crystals. Moreover, as the achievable coincidence time resolution (CTR) approaches 100 ps, the effect of the gamma-ray depth of interaction (DOI) becomes a contribution to mitigate. To address this issue, we explore two approaches using newly developed multi-channel HF electronics. First, a double-sided readout method retrieves DOI information by analyzing time and charge differences at both ends of a scintillator. Second, a single-sided readout employs a light-sharing mechanism with a matrix of depolished scintillators and a light guide to retrieve the DOI information. Both methods achieve state-of-the-art results, with a 20 mm LYSO:Ce matrix providing a CTR of 133 $\pm$ 2 ps and a DOI resolution of 2.2 $\pm$ 0.2 mm. To enhance detector sensitivity, these techniques are applied to high-stopping-power materials like BGO and heterostructured scintillators. Furthermore, we propose a novel algorithm that recovers inter-crystal scattering (ICS) events in pixellated detectors, estimating the crystal of first interaction, which can improve reconstructed resolution with better LOR delineation for coincidence events.

Primary experiment

Author: TERRAGNI, Giulia (CERN and Technische Universitaet Wien (AT))

Co-authors: LOWIS, Carsten (CERN and FH Aachen University of Applied Sciences (DE)); CATES, Joshua (Lawrence Berkeley National Laboratory); MARTON, Johann (Technische Universitaet Wien (AT)); PIZZICHEMI, Marco (Universita Milano-Bicocca (IT) and CERN); AUFFRAY HILLEMANNS, Etiennette (CERN)

Presenter: TERRAGNI, Giulia (CERN and Technische Universitaet Wien (AT))

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